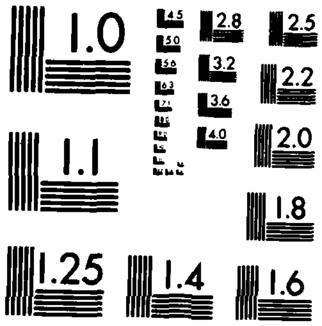
AD-A150 299 NEAR FIELD/FAR FIELD (NF/FF) ENERGY LOSS IN ELECTRIC DISCHARGE LASERS (ED..(U) ARMY MISSILE COMMAND REDSTONE ARSENAL AL DIRECTED ENERGY DIRE.. J H BENTLEY AUG 84 1/1

UNCLASSIFIED AMSMI/RH-84-5-TR SBI-AD-E950 650 F/G 20/5 NL

END



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL REPORT RH-84-5

NEAR FIELD/FAR FIELD (NF/FF) ENERGY LOSS IN ELECTRIC DISCHARGE LASERS (EDL'S): A MODE-MEDIUM INTERACTION

James H. Bentley
Directed Energy Directorate
US Army Missile Laboratory

AUGUST 1984

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898-5000

Cleared for public release; distribution unlimited.

DISPOSITION INSTRUCTIONS

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

DISCLAIMER

THE FINDINGS IN THIS REPORT ARE NOT TO BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION UNLESS SO DESIGNATED BY OTHER AUTHORIZED DOCUMENTS.

TRADE NAMES

USE OF TRADE NAMES OR MANUFACTURERS IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL INDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL HARDWARE OR SOFTWARE.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: TR-RH-84-5	2. GOVT ACCESSION NO.: AD-A150 299
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): NEAR FIELD/FAR FIELD (NF/FF) ENERGY LOSS IN ELECTRIC DISCHARGE LASERS (EDL'S): A MODE-MEDIUM INTERACTION	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): James H. Bentley	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Commander, US Army Missile Command, ATTN: AMSMI-RH, Redstone Arsenal, AL 35898-5245	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Commander, US Army Missile Command, ATTN: AMSMI-RH, Redstone Arsenal, AL 35898-5245	12. REPORT DATE: August 1984
	13. NUMBER OF PAGES: 12
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Cleared for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Laser, Mode-Medium Interaction, Parallel-Piped Burn-In, Medium Structure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

High energy CO_2 EDL's with unstable resonators exhibit a mode-medium interaction which spreads the focussed beam and causes loss in the far-field. Mirror edge Fresnelling may result in amplified feedback which causes a parallel-piped structure to be burned into the lasing medium. Possible confirming experiments are described.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

CONTENTS

I. INTRODUCTION

It has been determined from various experiments, that a far field energy loss is occurring in large atmospheric transverse excited EDL's fitted with unstable resonators of moderate magnification. It has further been observed that the near field burn pattern from such EDL's shows a striking pattern of crosshatched lines varying in size from one-fourth to one-half millimeter square, or more. A possible mechanism is suggested for this mode-medium interaction and an experiment(s) which may prove this mechanism to be conducted on the existing S^3 CO_2 laser device. A brief history of experimental results and interpretation of results are presented in the following sections of this report.

II. BACKGROUND

Experiments at both AVCO and Westinghouse, as well as others, have indicated that a NF/FF energy loss occurs in pulsed CO_2 TEA lasers. This effect began to be important after about 3 microseconds or so, although there was every reason to believe that a phenomenon mechanism was operating as early as the mode formation time. The expected energy in the far field central spot begins to be reduced in the 3 microsecond time frame and continues to worsen as time passes. This "lost" energy evidently appears in high angle diffraction/interference patterns, measured out to 5 milliradians, but perhaps existing tomuch higher angles. It has been argued that this mechanism is some sort of stimulated scattering which would necessarily result sooner or later in any gas laser. The argument is that the minute homogeneities existent in the laser medium gas would inevitably result in a high angle NF/FF energy loss. This argument seems insufficient.

III. EXAMINATION AND VERIFICATION OF THE THESIS

A. Analysis of the Phenomenon and a Proposed Mechanism

It is proposed that the NF/FF energy loss mechanism, as observed in our TEA lasers, is a phenomenon of the unstable resonator and the resultant crosshatched pattern observed at the near field position. Let us assume the following scenario. Given, is a pulsed CO_2 TEA laser with an unstable resonator. After the electric pulse begins, and as energy begins to appear as directional stimulated emission, a preferred mode of interaction of the resonator with the lasing medium begins to develop. This mode is not the simple non-nodal wavefront predicted by a simplified theoretical treatment of such a resonator, because the mirror edge Fresnelling of the exit pupil (the feedback mirror) is superimposed on the field. This is true because part of the Fresnel radiation from the mirror edge is fed back into the resonant cavity to be amplified and reamplified via stimulated emission, establishing itself as an integral part of the light field formed in what is known as the mode formation time.

Therefore, the laser light begins to appear as the mode is formed (tens of nanoseconds) and, of necessity, appears within the cavity as a light field of adjacent, thin parallelpipeds in two dimensions, the transverse spatial frequency of which is defined by the complicated Fresnel patterns set up within the resonant cavity. It is important to notice that this pattern exists in the light field only, as described by the mirror edge Fresnelling, and not in the laser medium. The light field is merely passing through the laser medium.

As the laser pulse matures, the effects of localized heating and cooling is felt exactly according to the parallelpiped geometry. The bright portions are lasing best and are heated due to lower state thermalization, while the dark portions retain more of their energy trapped in the metastable upper levels of CO_2 and N_2, and remain relatively cool. The localized heating differential results, in the medium sonic time frame, in the light field parallelpipeds being "burned" into the laser medium so as to form the medium's own corresponding parallelpipeds, with the medium's gas matter superimposing itself upon the light field's parallelpipeds. The result is a pressure differential and a change of density ($\Delta\rho$) between the two locations. This $\Delta\rho$ will correspondingly result in a difference in refractive index, Δn. As the medium structure (in the sonic time frame) begins to form, it interacts with the light field (via the Δn) at very low (grazing) angles so as to result in light piping and an effective large decrease in the exit pupil size for the laser. This interaction, much like the light field and the medium structure, should not be considered as a smooth, regular, or static event. Indeed, as potential variables in the resonator exercise their options, the situation should be dynamic. The far field total energy readings would average out this dynamic effect. The result would be an observed NF/FF energy loss manifesting itself in the time it takes TEA laser molecules to move the distances required (millimeters) to form the parallelpipeds. The "lost" energy would appear at high angle in directions and angles corresponding to the effective reduction in exit aperture size as defined by the medium parallelpipeds. The light piping effect would reinforce itself by tending to constrain laser radiation to the cold, dense, and dark portions of the parallelpipeds, while electrical pumping would continue to place energy into the medium as a whole, and the light portions of the parallelpipeds in particular. In short, the NF/FF energy loss would be driven by mirror edge Fresnelling and locked in, in a dynamic sort of way, by the light piping effect. It is important to note that the laser radiation is not zero for the dark portions of the field. The dark portions are lasing also, but merely at a reduced level.

B. Proposed Experimental Verification

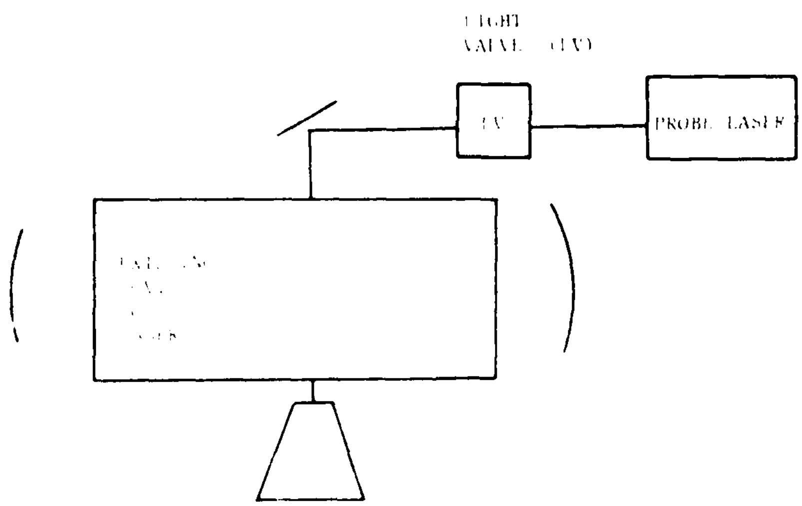
1. Description of Experiment

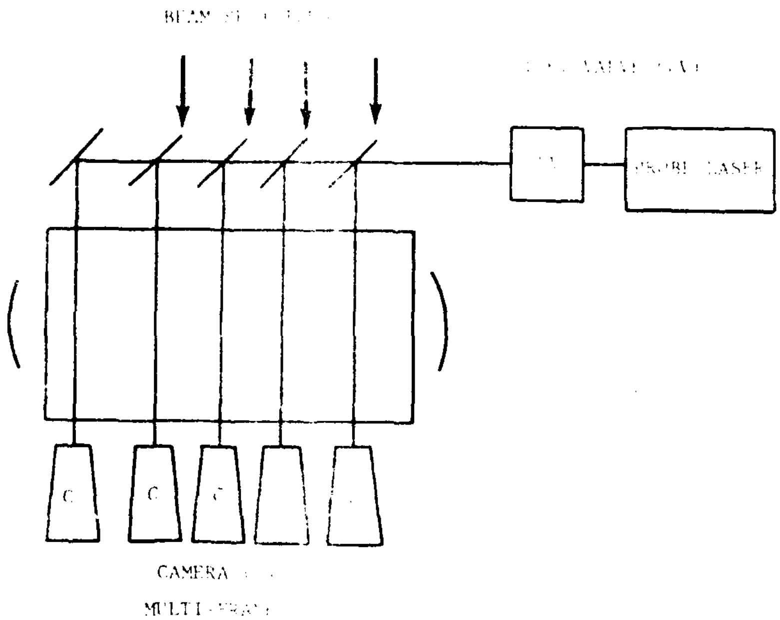
An experiment to check this theory could be done as follows: During the CO_2 laser pulse, another laser pulse (probe) is fed through the laser medium in a transverse direction. This pulse would be of another wavelength so as not to interfere with the CO_2 stimulated emission (this may not be required in a practical sense). If this transverse laser pulse (TLP) encounters a series of "lines" as defined by suggested parallelpipeds, then diffraction and interference should occur to project, in the far field, an in-line series of spots defining the diffracted orders of the incident laser spot. For this order scattering to occur to an observable extent, several things must be true. The parallelpipeds "burned" into the medium must be of such definition (large Δn) so as to be visible to the probe laser pulse. The probe laser pulse must occur after the time period required for the "burn-in" to occur. And finally, the recording film must be sensitive enough to record the small amount of energy present in the TLP.

To do this experiment on S^3, at least two holes (top and bottom) must be cut in the aluminum container and optical windows emplaced. The probe laser must be a powerful CW variety or a pulsed type, with a wavelength corresponding to a fast film. The wavelength need not be visible. "Light carving" equipment must be available (Pockels cells, etc.) along with mirrors and a good camera with a fast shutter, capable of electrical switching. A suitable film must be available.

This experiment can be done with a single beam pass in any accessible position along the resonator axis, or (with additional light carving equipment) with several transverse beams separated in time by light flight periods which may be varied at will. In the latter case, a "movie" of approximately five exposed frames would be possible, yielding a series of frames of the development of the parallelpipeds in the lasing medium as a function of time. Several variations of these two methods are possible, each providing various capabilities with various equipment.

2. Experimental Diagrams




BEAM
PROBE LASER
C
C
CAMERA
MULTI

DISTRIBUTION

	No. of Copies
Director US Army Materiel Systems Analysis Activity ATTN: AMXSY-MP Aberdeen Proving Ground, MD 21005	1
Central Intelligence Agency ATTN: OIA/TSO, Mr. L. Echenrode OSWR/DSD, Mr. G. Bock Washington, DC 20505	1 1
DOD Nuclear Effects Information and Analysis Center (DASIAC) Defense Technology Information Repository (DETIR) Kaman Tempo ATTN: Mr. F. Wimenitz 2560 Huntington Avenue Alexandria, VA 22303	1
DASIAC-DETIR Kaman Tempo ATTN: D. Reitz 816 State Street (P. O. Drawer QQ) Santa Barbara, CA 93102	1
Ballistic Missile Defense Program Office ATTN: DACS-EMI Washington, DC 20310	1
Defense Advanced Research Projects Agency ATTN: Director, Laser Division 1400 Wilson Boulevard Arlington, VA 22209	1
Director, Ballistic Missile Defense Advanced Technology Center PO Box 1500 ATTN: ATC-O, Mr. W. O. Davies Mr. M. Lavan Huntsville, AL 35807	1 1
TRW Systems Group ATTN: Mr. Don M. Culler Dr. Carl A. Flegal Mr. Norman F. Campbell Mr. Ken Uffelman One Space Park Redondo Beach, CA 90278	1 1 1 1

DISTRIBUTION (Concluded)

	No. of Copies
Westinghouse Research and Development Center	
ATTN: Dr. E. P. Riedel	1
Dr. S. A. Wutzke	1
1310 Beulah Road	
Pittsburgh, PA 15235	
Mathematical Sciences Northwest, Inc.	
ATTN: Mr. P. H. Rose	1
Mr. A. Hertzberg	1
2755 Northrup Way	
Bellevue, WA 98004	
Los Alamos Scientific Laboratory	
ATTN: Dr. K. Boyer (MS 530)	1
Dr. O. P. Judd	1
P.O. Box 1663	
Los Alamos, NM 87544	
AVCO - Everett Research Laboratory	
ATTN: Dr. G. Sutton	1
Dr. J. Dougherty	1
2385 Revere Beach Parkway	
Everett, MA 02149	
AFWL/AR	
ATTN: COL Keith G. Gilbert (ARE)	7
Kirtland AFB, New Mexico 87117	
AMSMI-R	1
-RH, COL Haddock	1
-RHA	1
-RHC, Mr. Scheiman	1
-RHS, Dr. Honeycutt	1
-RHS, J. Bentley	4
-LP	1
-RPR	15
-RPT Record Set	1

END

FILMED

3-85

DTIC